

COTTONWOOD DAM

MANUAL FOR OPERATION AND MAINTENANCE

**State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
1424 9th Avenue
P. O. Box 201601
Helena, MT 59620-1601**

**Originally Published June, 1995
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TABLE OF CONTENTS

	<u>Page</u>
PROJECT DESCRIPTION.....	1
Overview	1
Embankment	1
Outlet Works	1
Spillway	2
Drains	2
General Location Map (Figure 1)	4
Project Area Map (Figure 2)	5
Dam General Layout Map (Figure 3)	6
Monitoring Wells Map (Figure 4)	7
STATISTICAL INFORMATION	9
OPERATING PROCEDURES	13
Dam Operator.....	13
Method and Schedule of Operation	14
Safe Drawdown.....	15
Gate Operation	15
Spillway.....	15
Storage Determination.....	16
Weather Monitoring.....	16
Interaction with Other Dams	17
Emergency.....	17
INSPECTION AND MONITORING.....	19
Structural Features Inspection	19
Riprap Inspection	20
Monitoring Wells.....	20
Seepage	21
Seepage Monitoring	22
MAINTENANCE.....	23
Routine Maintenance.....	23
Annual Maintenance.....	24
Record Keeping	24
REFERENCES.....	26

APPENDICES.....	27
A. RATING CURVES AND TABLES.....	A1
Table 1. SLOPE/ELEVATION/STORAGE TABLE.....	A2
Table 2. ACTIVE STORAGE TABLE.....	A3
Table 3. SPILLWAY RATING CURVE AND TABLE.....	A4
Table 4. OUTFLOW RATING CURVE AND TABLE	A5
B. INSPECTION REPORT FORM	B1
C. O&M MANUAL DISTRIBUTION LIST.....	C1
D. MONITORING WELL LOGS	D1
E. PROJECT DRAWINGS.....	E1

PROJECT DESCRIPTION

OVERVIEW

Cottonwood Dam is owned by the Montana Department of Natural Resources and Conservation (DNRC) and is managed by the State Water Projects Bureau (SWPB) of the DNRC. The Shields Canal Company (herein called the “association”) operates and maintains the dam.

The dam is located on Cottonwood Creek, approximately 3 miles northwest of town of Wilsall in Park County. The reservoir impounds runoff from a drainage area of 34 square miles located in Park and Gallatin Counties (See Figures 1 and 2). Figure 3 provides a general layout of the dam, spillway and outlet works. Figure 4 shows the location of the monitoring wells.

Water from the reservoir is primarily used for irrigation. The reservoir is also used for water-based recreation.

EMBANKMENT

The zoned earthfill dam and earthfill dike were completed in 1953. The dam is 39-feet-high and 610-feet-long while the dike is up to 8-feet-high and 825-feet-long. In 1986, significant construction was completed to rehabilitate the spillway and riprap on the upstream face of the dam.

OUTLET WORKS

The dam's outlet works consist of a wet tower and a single 36-inch diameter slide gate with controls at the top of the tower. The low-level outlet conduit consists of 197 feet of 10 gauge, 36-inch diameter corrugated metal pipe double bituminous coated (inside and outside) with a paved invert. The outlet conduit discharges into the spillway stilling basin.

In 2003, the Bureau of Reclamation performed a visual inspection and ultrasonic thickness survey of the corrugated metal outlet pipe. The ultrasonic thickness survey results indicated that the pipe wall thickness is greater than the wall thickness originally specified. This is not unusual, as pipe manufacturers tend to make the pipe wall thickness slightly larger than the thickness specified to ensure they meet minimum wall thickness requirements. Due to the extra wall thickness, the Bureau concluded the surface rusting on the corrugated metal pipe was not a concern at that time.

SPILLWAY

The spillway is located in the right abutment. In 1986, the dam underwent a spillway rehabilitation project that increased the capacity of the spillway. The project also constructed a guard dike, a new baffled apron chute and increased the height of the chute sidewalls. The purpose of the guard dike is to maintain storage in the reservoir and allowed the removal of the flashboards on the spillway, thus increasing the ultimate capacity of the spillway.

The spillway is an uncontrolled concrete chute with a 70-foot-wide guard dike and a 20-foot-wide ogee crest at the throat of a 20-foot-wide chute with concrete baffle blocks. The upstream guard dike is at elevation 5,102.5 feet that is the same elevation as the pre-existing wooden flashboards (the flashboards were removed during the rehabilitation work).

DRAINS

The drawings for the dam show a toe drain that exits into the outlet channel downstream from the outlet-spillway stilling basin. The drain has not been located. An unsuccessful attempt was made with a backhoe in 1985 to locate the drain.

Approximately 15 feet downstream from the outlet wingwall on the left side of the outlet channel, water is flowing into the channel. This may be the exit for the toe drain. The flowing water at this location was first observed in 1992. The drawings show the approximate drain exit point into the channel near this location.

When the spillway was reconstructed in 1986, drains were installed under the floor to collect the seepage that flows through the right abutment. The drains consist of drains installed in filter gravel outside and adjacent to each of the spillway sidewalls, a central drain with collector pipes under the spillway floor in filter gravel, and two side drains adjacent to the center drain under the floor. The outside wall drains exit into the spillway through the downstream side of one of the baffle blocks. The under-floor drains exit through the spillway floor above the normal water surface of the stilling basin. Gravel underlies the toe of the spillway allowing excess seepage to flow through weep/drain holes in the spillway end wall.

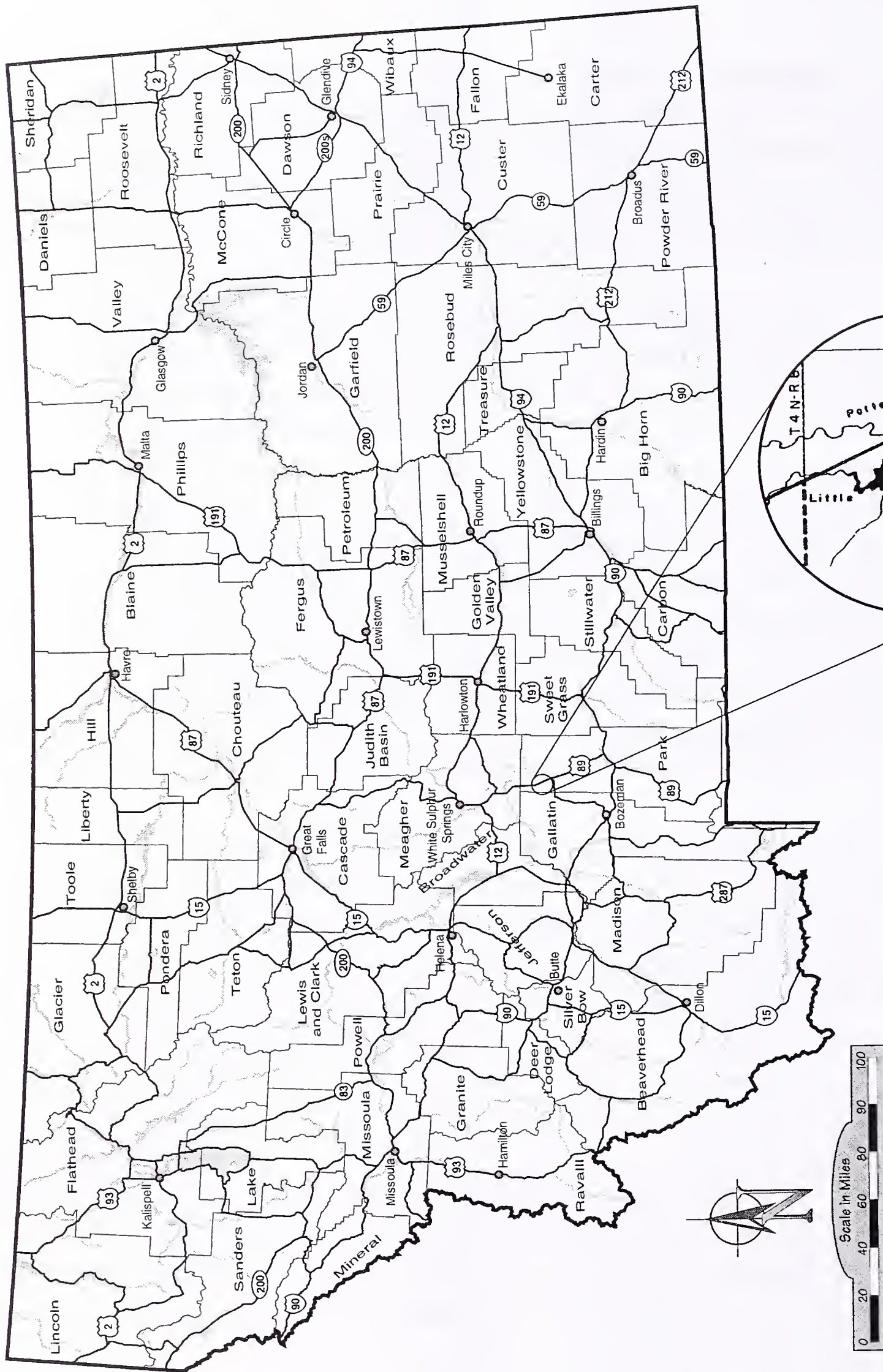


Figure 1. Cottonwood Reservoir Location Map

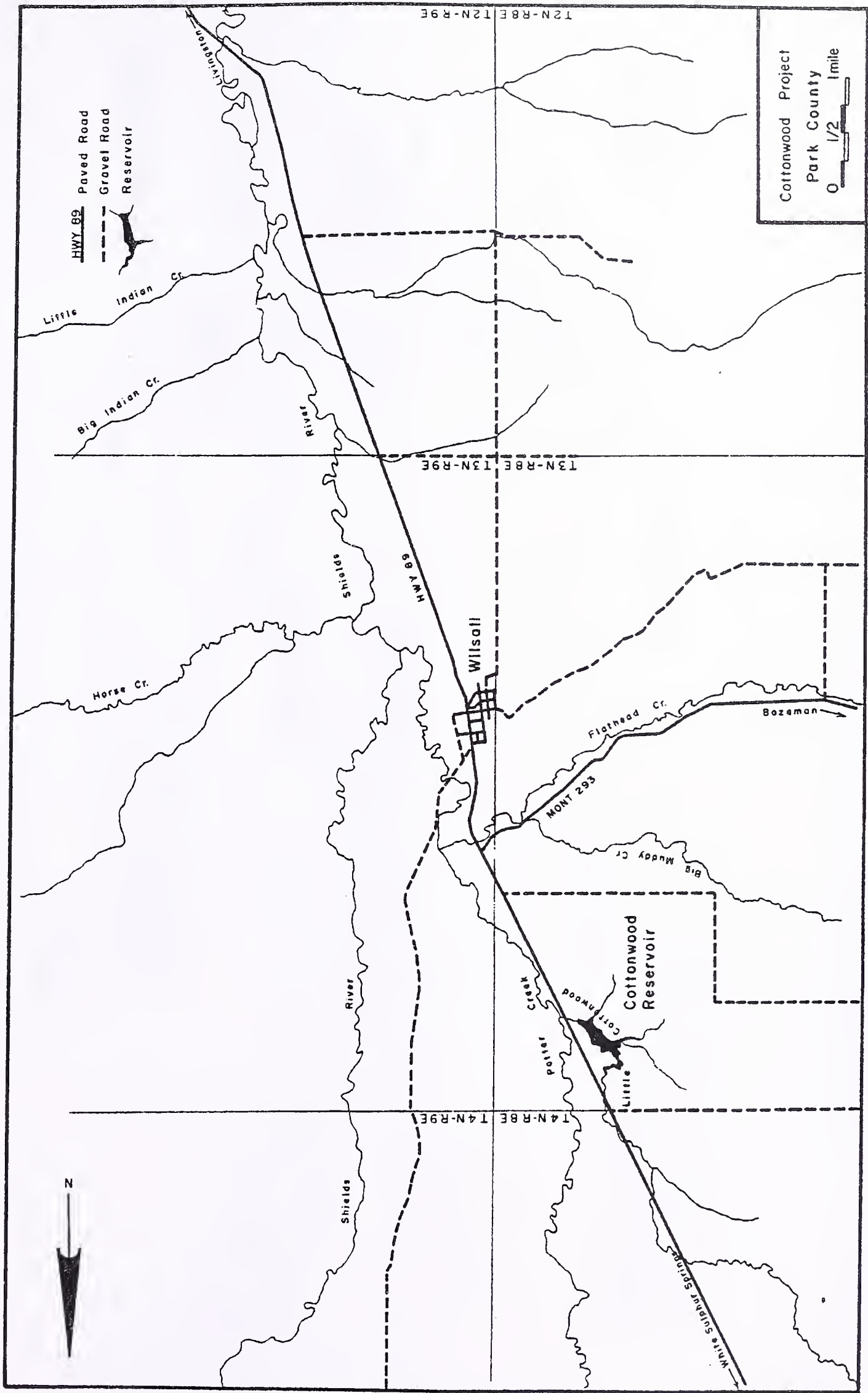


Figure 2. Cottonwood Project Map

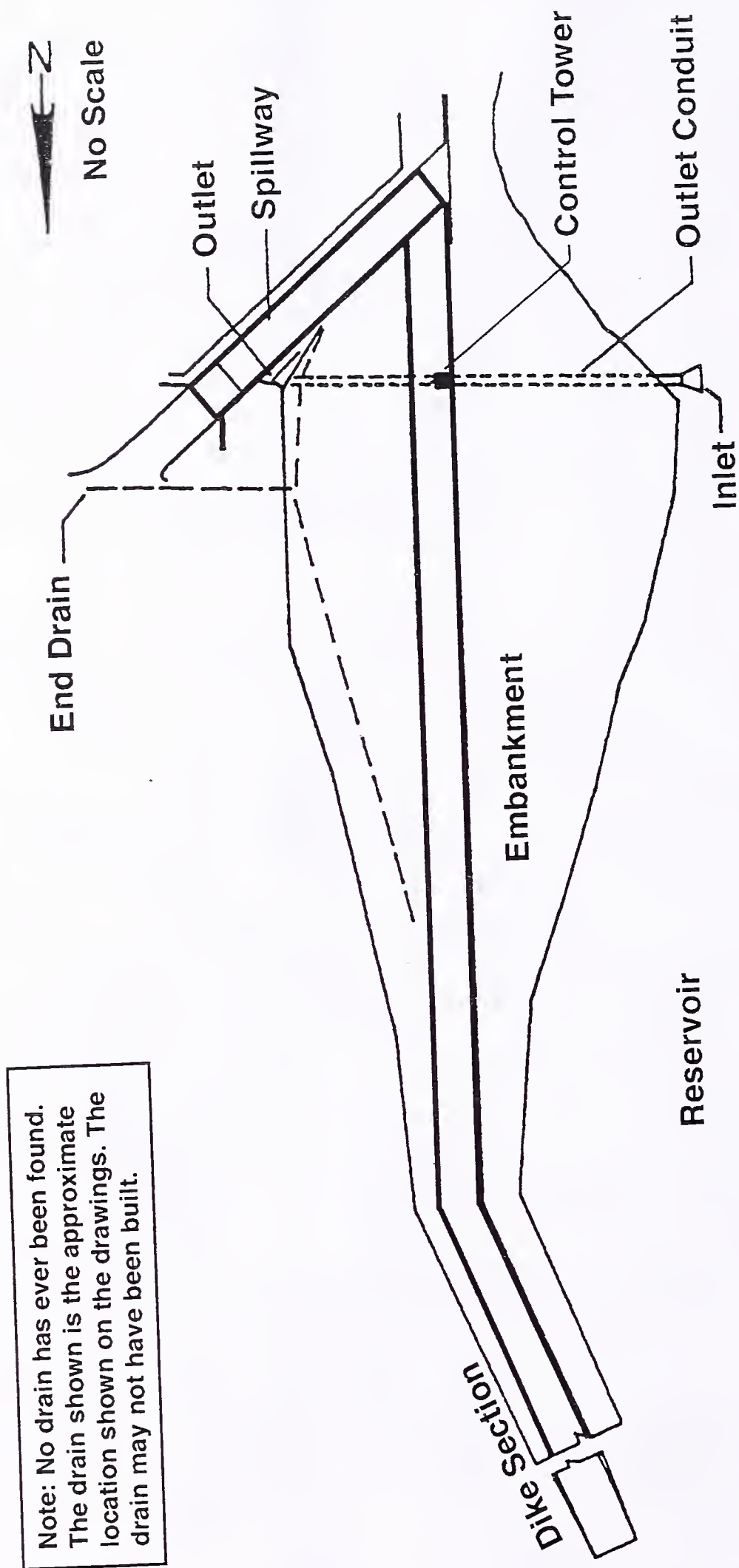


Figure 3. Cottonwood Dam General Layout Map



No Scale

• Drill Hole Location

▲ Beck Piezometers

(B2-B8. B1 has been destroyed.)

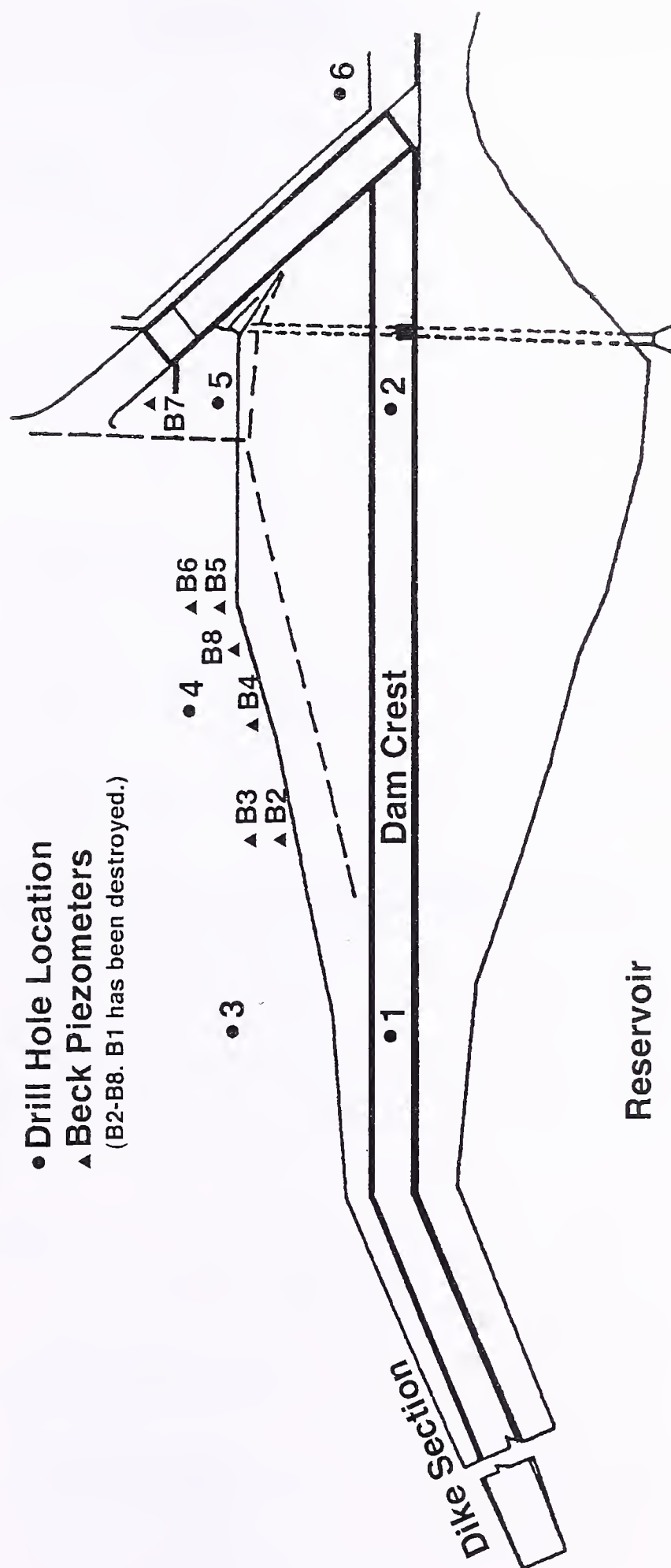


Figure 4. Cottonwood Dam Monitoring Wells Location

STATISTICAL INFORMATION

1. General

a. Owner	Montana Department of Natural Resources and Conservation (DNRC)
b. Operator	Shields Canal Company
c. Location	Sections 1, 2, 11, and 12, Township 3 North, Range 8 East
d. Latitude	46° 02' 00"
Longitude	110° 40' 54"
e. County--State	Park--Montana
f. Watershed Location	Cottonwood Creek (tributary to Potter Creek)
g. Drainage Area	34 square miles

2. Principal Elevations (feet above mean sea level)

a. Minimum Dam Crest	5,108.7 feet
b. Guard Dike Crest	5,102.5 feet
c. Spillway Ogee Crest	5,100.5 feet
d. Outlet Design Invert	5,072.0 feet

3. Reservoir

a. Length of Maximum Pool (approximate)	0.9 mile
b. Maximum Reservoir Level of Record	5103.08 ft
c. Surface Area at Guard Dike Crest	235 acres

4. Storage

- | | |
|---|-----------------|
| a. Maximum Pool
(pool at dam crest) | 3,670 acre-feet |
| b. Total Storage
(pool at guard dike crest) | 1,905 acre-feet |
| c. Active Storage
(total storage – dead storage) | 1,905 acre-feet |
| d. Dead Storage
(pool at invert of intake structure) | 0 acre-feet |

5. Hydrology

- | | |
|--|---|
| a. Inflow Design Flood
(HKM -- 1986) | 14,200 cfs -- Probable
Maximum Flood |
| b. Spillway Compliance
Analysis For 0.62 LOL
1/2005 (Kraig McLeod) | 2,660 cfs |
| c. 500-Year Flood | 1,770 cfs |
| d. 100-Year Flood | 1,120 cfs |

6. Dam Embankment

- | | |
|---------------------|--|
| a. Type | Zoned earthfill |
| b. Hydraulic Height | 39 feet |
| c. Crest Length | 610 feet
(includes spillway -- 20 feet) |
| d. Crest Width | 20-26 feet |
| e. Downstream Slope | 1v on 2.0h |
| f. Upstream Slope | 1v on 3.0h |

7. Dike Embankment

- | | |
|---------------------|------------|
| a. Type | Earthfill |
| b. Hydraulic Height | 8 feet |
| c. Crest Length | 825 feet |
| d. Crest Width | 10-18 feet |
| e. Downstream Slope | 1v on 2.0h |
| f. Upstream Slope | 1v on 4.0h |

8. Spillway

- | | |
|--|--|
| a. Location | Right abutment |
| b. Type | Uncontrolled guard dike with an ogee crest |
| c. Width | Guard dike - 70 feet
Ogee crest - 20 feet |
| d. Chute Width | 20 feet |
| e. Maximum Capacity
(pool at dam crest) | 1,375 cfs |

9. Outlet Works

- | | |
|------------------------------------|--|
| a. Size | A single 36-inch diameter corrugated steel pipe, 10-gauge, double bituminous coated with paved invert. |
| b. Length | 197 feet |
| c. Control | A single 36-inch diameter vertical slide gate located in a rectangular wet tower with control at dam crest |
| d. Capacity
(pool at dam crest) | 112 cfs |
| e. Trashrack | Yes |

10. Brief History

- a. July 7, 1953 – The State of Montana Water Conservation Board awarded a contract Stanley H. Arkwright Company to construct the Cottonwood Creek Storage Project for a total cost of \$58,014.15
- b. 1955 – The State of Montana Water Conservation Board drilled and pressure grouted clay material into 790 linear feet of holes drilled into the dam. The grouting was an effort to tighten up laminated and crevice sand rock foundation under the dam. Approximate cost of \$2,500.
- c. May 1982 - Three holes were drilled. Two of these holes were destroyed when the spillway was rehabilitated in

1986. The remaining hole is located on the south side of the spillway.

- d. 1985 - The drawings for the dam show a toe drain that exits into the outlet channel downstream from the outlet-spillway stilling basin. An unsuccessful attempt was made with a backhoe to locate the drain.
- e. 1986 - Cottonwood dam underwent a spillway rehabilitation project that increased the capacity of the spillway. The project also constructed a guard dike, a new baffled apron chute and increased the height of the chute sidewalls. The purpose of the guard dike is to maintain storage in the reservoir and allowed the removal of the flashboards on the spillway thus increasing the ultimate capacity of the spillway.
- f. In 1997 and 1998, eight "Beck-type" observation wells were installed along the toe of the dam in the seepage area and below it. In 1999 #1 was abandoned.
- g. 1999 - Five drill holes with 10 piezometer wells (two in each hole) were installed at Cottonwood Dam. Two of the drill holes were through the crest of the dam. Three drill holes were located along the toe of the dam.

OPERATING PROCEDURES

The Shields Canal Company operates Cottonwood Dam to provide an adequate supply of irrigation water to meet contracts with the water users without exceeding safe storage or flow levels, and to insure safe operation of the project.

DAM OPERATOR

The responsibility for the daily operation of the dam and reservoir rests with the association and its dam operator. The dam operator is generally authorized to operate the reservoir to meet the association's goal of providing storage and regulation in support of agriculture. The dam operator's specific responsibilities are to:

1. Operate the mechanical features of the outlet works.
2. Coordinate filling of the reservoir and the release of water.
3. Notify the SWPB of unusual occurrences such as vandalism, impending flood, excessive seepage, problems with the outlet, or other unusual situations that may occur.
4. Perform various maintenance tasks.
5. Monitor weather conditions.
6. Monitor seepage.

Typically, the outgoing dam operator, association, and the SWPB train a new dam operator. The dam operator's training focuses on the mechanical operation of the gate, measurement of the storage level, measurement of the rate of water release, and record keeping.

The dam operator is normally available to observe the dam and perform operating functions weekly during the filling and irrigation season and monthly at other times of the year. Communication among the dam operator, the association, and the SWPB typically takes place by telephone. Although not routinely available, during emergencies or unusual occurrences, radio

communication may be established so that the dam operator can speak directly with county authorities and communicate indirectly with the SWPB (**see Cottonwood Dam Emergency Action Plan**).

METHOD AND SCHEDULE OF OPERATION

For most the year, the outlet remains in a closed position. Any snowmelt or other runoff is stored in the reservoir until filled. Water in excess of the storage capacity is simply allowed to discharge over the spillway. According to the dam operator, the spillway spills about seven out of ten years. The date chosen for opening the outlet varies according to the needs of the irrigators, but it will be, generally, near the end of June or first half of July. There is one (1) contract for one thousand three hundred ninety five (1,395.00) marketed acre feet of water. The gate is typically set to release about 12 to 15 cfs when opened. Releases are then adjusted as needed according to stream conditions and the requirements of the water users. The capacity of the distribution canal limits useable releases to about 18 cfs. The gate is then typically closed before the first of September. The water may be released from May 1 through September 30. The typical total annual drawdown of the reservoir is estimated to be about 12 -15 feet.

Maximum Winter Storage. The maximum reservoir elevation for winter storage is 5,097.5 feet with 957 acre-feet of storage. This winter maximum helps prevent damage to the riprap and embankment from wind-driven waves and ice.

Minimum Winter Storage. The minimum reservoir elevation for winter storage is 5083.4 feet with 50 acre-feet of storage. This winter minimum helps prevent ice damage to the inlet structure for the outlet works.

SAFE DRAWDOWN

The SWPB recommends that drawdown rates should not exceed one foot per day. Under most circumstances, the operating gate should not be used to rapidly release water from the reservoir. Operation of the gate for anything other than providing water normal irrigation demand may result in damage to the dam and downstream structures.

GATE OPERATION

The theoretical maximum capacity of the outlet conduit with the gate wide open when the reservoir is at the dam crest is 112 cfs. The outlet works are to be used for controlling the releases of irrigation water and not for providing emergency relief.

The gate is normally opened between three (3) and five (5) inches to meet irrigation demand. In 1982 the gate was safely opened to eighteen (18) inches to get water off of the spillway for concrete coring. With the gate open at 18 inches there was a substantial amount air demand through the vent, and some erosion was observed in the downstream channel. DNRC –SWPB personnel should be contacted prior to opening the gate for anything other than normal irrigation releases.

The outlet gate is operated manually with a hand crank. The maximum gate opening is 3 feet. Openings in excess of this amount may damage the gate or gate frame. The gate opening is measured on the exposed portion of the gate stem between the top of the pedestal and the bottom of the stop nut.

SPILLWAY

The spillway has a capacity of 1,375 cfs at the minimum dam crest elevation. The spillway-rating table is shown in Appendix A.

STORAGE DETERMINATION

Storage in the reservoir and the elevation of the reservoir surface are determined by taking a slope measurement. Measure in feet from the rebar pin located along the north side of the gate operating pedestal concrete pad to the water surface. The elevation of the reservoir surface and the storage can then be found using the Slope-Elevation-Storage Table (Table 1) in Appendix A.

If water is flowing over the guard dike in front of the spillway, the reservoir storage and elevation can be determined by measuring the depth of the water going over the guard dike. The elevation of the guard dike is 5,102.5 feet. Add the depth of the water going over the guard dike to 5,102.5 to find the elevation of the water surface. Once the reservoir surface elevation is determined, the reservoir storage is found using the Elevation/Storage Table (Table 2) in Appendix A.

WEATHER MONITORING

Weather conditions will be monitored by the dam operator through normal local weather forecasts and the National Weather Service.

If severe flooding is anticipated, the NWS Billings Office **(800-240-4596 or 406-652-2314)** should be contacted for information about the storm, such as the estimated storm intensity and duration, runoff duration (above base flow), and the total flood volume of the storm in the Cottonwood Creek drainage.

INTERACTION WITH OTHER DAMS

The only dams located downstream of the Cottonwood Dam are irrigation diversion dams. The safety of these dams is not affected by the operation of Cottonwood Dam during either normal or emergency operations. Therefore, interaction with other dams is not a concern of the normal operation of Cottonwood Dam.

EMERGENCY

If it appears that Cottonwood Dam is about to breach, or during emergency operations, the dam operator will initiate the **Cottonwood Emergency Action Plan**.

INSPECTION AND MONITORING

The SWPB conducts annual inspections of the dam. Appendix B includes an example of a SWPB inspection report form. In addition to annual inspections, SWPB personnel will inspect the dam and reservoir during and after heavy runoff, severe rainstorms, and severe windstorms during high storage periods and after an earthquake.

STRUCTURAL FEATURES INSPECTION

Structural features include the dam embankment, dike, spillway and outlet works. The SWPB inspects these structures annually as part of its inspection program. Items to be checked or noted include, but are not limited to:

1. Outlet Works

- a. Any differential settlement or movement resulting in cracking of the conduit.
- b. Erosion of the seals or corrugated metal pipe by cavitation immediately downstream of the gates
- c. Major seepage of water into the conduit or emerging at spillway sidewall along side conduit
- d. Major deterioration of exposed concrete due to freeze/thaw cycles or sulfate reactions
- e. Operation of the gate
- f. Corrosion of any metal
- g. Proper lubrication of pedestal
- h. Unobstructed operation of the air vent

2. Embankments

- a. Erosion gullies in dam and dike faces.
- b. Damage from burrowing animals or vegetation.
- c. Displacement or loss of riprap protection.

- d. Displacement of fill, sink holes, slumps etc.
 - e. Any seepage.
4. Spillway
- a. Cracking or displacement of the concrete floor, baffle blocks, and sidewalls.
 - b. Seepage into, underneath or along the sides of spillway.
 - c. Excessive sediment or debris at guard dike or ogee crest.
 - d. Erosion, undermining, or unaccountable flow at bottom of spillway.
 - e. General deterioration.
 - f. Blockage of the approach or exit channel.

RIPRAP INSPECTION

The riprap on the upstream face of the dam should be at least 30 inches thick. Immediately after the occurrence of high water, the riprap will be inspected and additional riprap added if needed.

MONITORING WELLS

Three holes were drilled in May 1982. Two of these holes were destroyed when the spillway was rehabilitated in 1986. The remaining hole is located on the south side of the spillway.

Seven "Beck" piezometers were installed by the SWPB along the toe of the dam in the left abutment in August 1997. An eighth "Beck" piezometer was installed by the SWPB in April 1998. Currently seven piezometers remain.

Five holes were drilled in November 1999. Two of these were drilled along the top of the dam crest and the remaining three holes were drilled along the toe of the dam embankment. (See Figure 4.) Soil profiles of the drill holes and details as to how the wells were constructed are shown in Appendix D.

SEEPAGE

There is one seepage area at the toe of the dam and two seepage areas along the outlet channel downstream of the dam. Following is a summary of these seeps.

Left Abutment Toe Area. This seep area is located in the left abutment at the toe of the embankment. The seepage area is approximately 40 feet in diameter and produces no surface flow. The seep is evident based on the greenness and density of the vegetation, water-type grasses and sedges, and the dampness of soil in this area. This seep has been observed at all pool elevations.

Left Side Of The Outlet Channel. This seep is located on the left side of the outlet channel about 15 feet downstream of the end of the spillway. This seep produces a fairly constant clear flow from an area about 3-4 feet in diameter. This seep may be flowing from the drain; however the specific location of the toe drain has not been confirmed. A pipe has been installed at this location to make collection and flow measurement easier. The flow varies from 0 to about 7 gallons per minute depending on the elevation of the reservoir pool.

Outlet Channel Downstream From The Dam. This seepage area is along the outlet channel about 250 feet below the end of the spillway. This seepage area exits on both sides of the channel, and is characterized by standing water and water-type plants. The seepage in this area may be passing through the weathered zones in the laminated sandstone bedrock of the left abutment. The seep varies from being damp to flowing less than a gallon per minute, and has been observed at all pool elevations.

SEEPAGE MONITORING

The monitoring wells and seepage areas at the dam are observed and monitored by the dam operator, DNRC Bozeman Regional Office, and SWPB during regular visits; and may be measured by the SWPB during annual inspections.

The instruments are generally measured once per month in March, April, July, August, September, and October; and twice per month in May and June. Measurements may be taken during the winter months (November, December, January, February) depending on weather conditions. The monitoring data is maintained by the SWPB in Helena.

MAINTENANCE

The association is responsible for routine maintenance of the project. The SWPB may identify items that need maintenance or repair during the annual report.

ROUTINE MAINTENANCE

To protect the dam embankment and dike and keep them in good order, the dam operator, during regular visits to the dam, will watch for and identify any potential maintenance requirements. As soon as a need is identified, the dam operator needs to schedule and perform the routine maintenance.

Items that may need occasional attention include, but are not limited to:

1. *Lubrication of gate-operating mechanism.*
2. *Debris or sediment restricting the spillway inlet or the outlet works.* Accumulated debris that could affect the operation of these appurtenances should be removed at once, with all debris removed at least annually.
3. *Erosion gullies on embankment or dike.* Development of gullies should be checked immediately. Gullies should be filled, compacted and seeded. Particular attention will be paid to the abutment contact areas and the downstream face.
4. *Rodent damage.* The rodents will be removed or destroyed, and any burrows holes should be filled immediately.
5. *Upstream slope riprap.* The upstream face riprap will normally be observed annually, but may occasionally need repairs because of high water or wave action.
6. *Vegetative cover on downstream slopes and dike.* Good vegetative cover must be maintained, but large brush should be removed.
7. *Noxious weeds.* Noxious weeds on and around the dam embankment and around the reservoir should be sprayed at

least on an annual basis.

8. *Clean spillway wall tops.* Spillway wall tops should be clear of any dirt, rocks, grass, brush, and overhanging vegetation.
9. *Repair joints and seal cracks in the spillway*

ANNUAL MAINTENANCE

The SWPB conducts annual inspections of Cottonwood Dam and reservoir. During these inspections, any items that require maintenance are identified and recorded. Items that may need annual maintenance include the spillway, outlet works, gate, riprap, monitoring wells, and the dike. Other routine items needing immediate attention, such as removing brush will be noted.

After the inspection, the SWPB sends the association a Dam Safety Inspection Report and a Maintenance Schedule Report. The reports identify items that need maintenance and provide a schedule of when the maintenance tasks need to be completed. The association is responsible for performing the maintenance items within the times specified.

The dam operator or association members may perform the maintenance tasks. However, major repairs will likely be handled by a contractor. The SWPB may assist in contracting for repairs and may supervise the repair work.

RECORD KEEPING

The SWPB maintains records, including photographs, of all inspections and maintenance requirements. These records also include seepage monitoring observations and monitoring well measurements. Anyone who wants to review these records may do so in the SWPB's office at the Department of Natural Resources and Conservation in Helena Montana.

The dam operator will keep records of the reservoir elevations, seepage observations, seepage measurements, and any unusual conditions. These records may be reviewed at the dam operator's house.

REFERENCES

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APPENDICES

APPENDIX A
RATING CURVES AND TABLES

TABLE 1. SLOPE- ELEVATION-STORAGE TABLE
COTTONWOOD RESERVOIR

Table prepared by DNRC 8/27/1997.
Storage values based on 1952 original surveys of the reservoir.
The 0+00 pin is located on the north side of the operating gate concrete pad.

Top of Operating Gate Concrete Pad	5,109.0 feet
Dam Crest	5,108.7 feet
Guard Dike Crest Elevation	5,102.5 feet

DISTANCE feet	ELEVATION feet	STORAGE acre-feet				DISTANCE feet	ELEVATION feet	STORAGE acre-feet
0 Top Pin 1	5108.99	3,797				35	5099.49	1,284
1	5108.80	3,741				36	5099.19	1,229
2	5108.61	3,685				37	5098.89	1,175
3	5108.43	3,631				38	5098.60	1,125
4	5108.24	3,575				39	5098.30	1,072
5	5108.05	3,519				40	5098.00	1,020
6	5107.83	3,454				41	5097.65	976
7	5107.61	3,389				42	5097.31	933
8	5107.40	3,326				43	5096.96	890
9	5107.18	3,261				44	5096.62	849
10	5106.96	3,196				45	5096.27	807
11	5106.65	3,104				46	5095.91	765
12	5106.35	3,016				47	5095.55	728
13	5106.04	2,924				48	5095.18	689
14	5105.74	2,835				49	5094.82	654
15	5105.43	2,743				50	5094.46	621
16	5105.08	2,640				51	5094.30	607
17	5104.73	2,536				52	5094.14	593
18	5104.37	2,430				53	5093.97	577
19	5104.02	2,326				54	5093.81	563
20	5103.47	2,166				55	5093.65	549
21	5102.91	2,008				56	5093.26	513
22	5102.64	1,940				57	5092.87	481
23	5102.37	1,873				58	5092.47	453
24	5102.10	1,805				59	5092.08	426
25	5101.83	1,745				60	5091.69	398
26	5101.60	1,698				61	5091.52	386
27	5101.37	1,651				62	5091.36	375
28	5101.13	1,601				63	5091.19	363
29	5100.90	1,555				64	5091.03	352
30	5100.67	1,510				65	5090.86	342
31	5100.43	1,462				66	5090.36	313
32	5100.20	1,417				67	5089.87	285
33	5099.96	1,370				68	5089.37	256
34	5099.73	1,328						
DISTANCE	ELEVATION	STORAGE				DISTANCE	ELEVATION	STORAGE

TABLE 2. ACTIVE STORAGE IN ACRE-FEET**COTTONWOOD RESERVOIR**

ELEV	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5,072	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5,073	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
5,074	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
5,075	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
5,076	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
5,077	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9
5,078	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8
5,079	8	8	9	9	9	9	10	10	10	11
5,080	11	11	12	12	13	13	14	14	15	15
5,081	16	17	18	19	20	21	22	23	24	25
5,082	26	28	29	31	32	34	36	37	39	40
5,083	42	44	46	48	50	52	55	57	59	61
5,084	63	66	68	71	74	76	79	82	85	87
5,085	90	93	96	99	102	105	107	110	113	116
5,086	119	122	125	129	132	135	138	141	145	148
5,087	151	155	159	162	166	170	174	178	181	185
5,088	189	194	198	203	207	212	217	221	226	230
5,089	235	241	246	252	258	263	269	275	281	286
5,090	292	298	304	309	315	321	327	333	338	344
5,091	350	357	364	371	378	385	392	399	406	413
5,092	420	427	434	441	448	455	462	469	476	483
5,093	490	499	508	517	526	535	544	553	562	571
5,094	580	589	598	607	616	625	634	643	652	661
5,095	670	680	691	701	712	722	733	743	754	764
5,096	775	787	799	811	823	835	847	859	871	883
5,097	895	907	920	932	945	957	970	982	995	1007
5,098	1020	1037	1055	1072	1090	1107	1125	1142	1160	1177
5,099	1195	1213	1231	1250	1268	1286	1304	1322	1341	1359
5,100	1377	1397	1417	1436	1456	1476	1496	1516	1535	1555
5,101	1575	1595	1616	1636	1657	1677	1698	1718	1739	1759
5,102	1780	1805	1830	1855	1880	1905	1930	1955	1980	2005
5,103	2030	2059	2088	2117	2146	2175	2204	2233	2262	2291
5,104	2,320									

NOTE: Storage table based on 1952 original hand surveys of the reservoir.

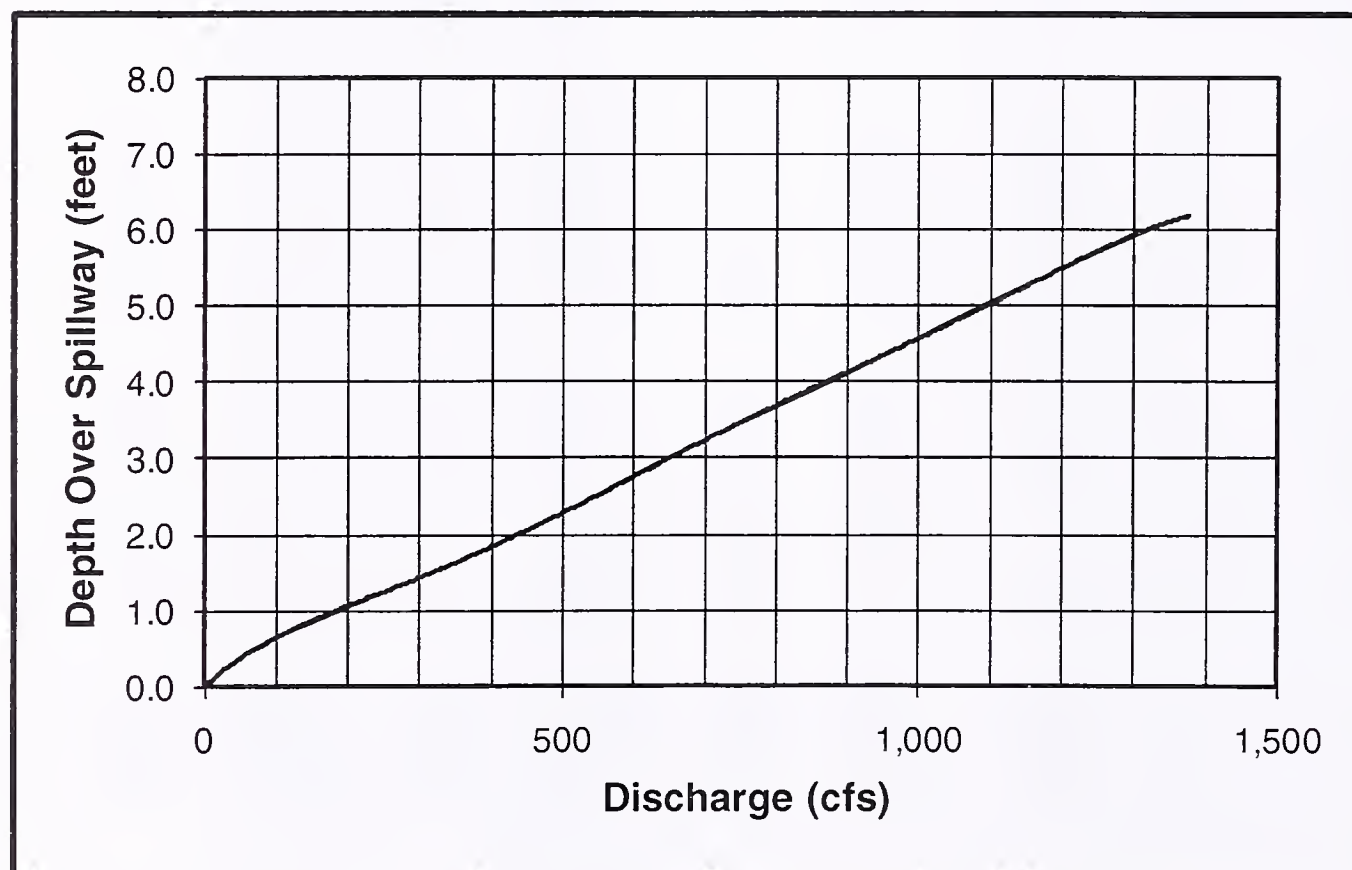
Top of Concrete Tower Elevation --- 5,109.0 feet

Guard Dike Crest Elevation --- 5,102.5 feet

TABLE 3. SPILLWAY DISCHARGE

COTTONWOOD RESERVOIR

Depth Over Crest (feet)	Elevation (feet)	Discharge (cfs)
0.0	5,102.50	0
0.5	5,103.00	65
1.0	5,103.50	188
2.0	5,104.50	436
3.0	5,105.50	646
4.0	5,106.50	878
5.0	5,107.50	1,088
6.0	5,108.50	1,324
6.2	5,108.70	1,375

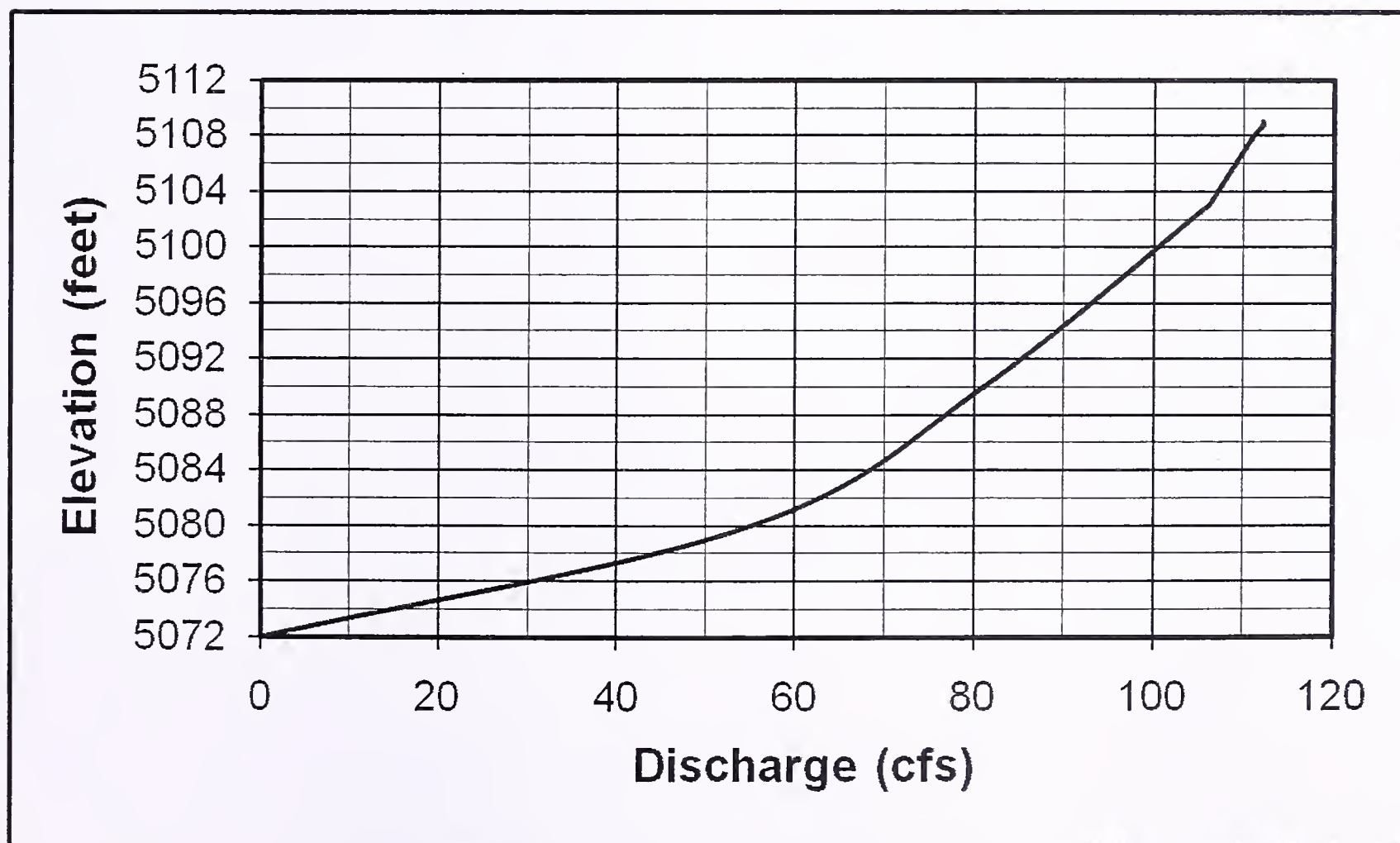


Note: Data based on spillway rehabilitation design by HKM (1986).

TABLE 4. OUTLET DISCHARGE
COTTONWOOD RESERVOIR

Reservoir Elevation (feet)	Discharge (cfs)	Comment
5072	0	
5080	55	
5090	81	
5102.5	105	Guard Dike Crest
5103	106	
5104	107	
5105	108	
5106	109	
5107	110	
5108	111	
5108.74	112	Minimum Dam Crest
5109	112	

Note: Discharge assumes operating gate is completely open.



Note: Data from the Corps of Engineers Phase 1 Inspection Report (1981).

APPENDIX B
INSPECTION REPORT FORM

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
DAM SAFETY INSPECTION REPORT

NAME OF DAM _____
DATE INSPECTED _____

INVENTORY NO. _____
HAZARD CATEGORY _____
TYPE OF DAM _____
YEAR BUILT _____

OWNER _____
OPERATOR _____
STREAM _____
DRAINAGE AREA _____

Reservoir Storage Status

	Water Surface Elevation (feet)	Storage (acre-feet)
At time of inspection	_____	_____
At spillway crest	_____	_____
At min. dam crest elevation	_____	_____

ITEM	YES	NO	REMARKS
------	-----	----	---------

1. EMBANKMENT

A. Crest -- Height= _____ Length= _____ Width= _____

(1) Any visual settlements?			
(2) Any misalignments?			
(3) Any cracking?			
(4) Any traffic damage?			
(5) Other?			

--	--	--	--

ITEM	YES	NO	REMARKS
------	-----	----	---------

1. EMBANKMENT (continued)

B. Upstream Face -- Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Is riprap protection adequate?			
(5) Any stone deterioration?			
(6) Any visual settlement, slumps, sloughing, depressions or bulges?			
(7) Adequate grass cover?			
(8) Debris on the dam face?			
(9) Other?			

C. Downstream Face--Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Any visual settlement, slumps, sloughing, depressions or bulges?			
(5) Is the toe drain dry?			
(6) Are the relief wells flowing?			
(7) Any boils at the toe?			
(8) Any seepage areas?			
(9) Any traffic or animal damage?			
(10) Any burrowing animals?			
(11) Adequate grass cover?			
(12) Other?			

D. Amount and Type of Vegetation on the Dam

--

ITEM	YES	NO	REMARKS
------	-----	----	---------

2. ABUTMENT CONTACTS

A) Any erosion?			
B) Any visual differential movement?			
C) Any cracks?			
D) Any seepage present?			
E) Other?			

3. OUTLET WORKS

A. Intake Structure -- Size=

(1) Any settlement?			
(2) Any tilting?			
(3) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(4) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(5) Metal appurtenances:			
a. Any corrosion present?			
b. Any breakage present?			
(6) Trash rack?			
a. Condition?			
b. Anchor system secure?			
(7) Other?			

ITEM	YES	NO	REMARKS
------	-----	----	---------

3. OUTLET WORKS (continued)

B. Conduit -- Type = Size =

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Is the conduit metal?			
a. Any corrosion present?			
b. Protective coatings adequate?			
(4) Is the conduit misaligned?			
(5) Any calcium deposits?			
(6) Other?			

C. Gates and Tower

(1) Gates:			
a. Size: Operating:		Emergency:	
b. Type: Operating:		Emergency:	
(2) Controls operational?			
(3) Controls lubricated?			
(4) Operational problems?			
(5) Leakage around gates?			
(6) Condition of gate seals?			
(7) Any cavitation damage? If so, describe?			
(8) Describe air vent-size and condition.			

ITEM	YES	NO	REMARKS
------	-----	----	---------

3. OUTLET WORKS (continued)

C. Gates and Tower (continued)

(9) Is there a jet pump?			
a. Is it operational?			
b. Leakage?			
(10) Is the tower dry? _____ wet?			
(11) Any seepage in the tower?			
(12) Condition of the tower?			
(13) Any safety problems?			
(14) Ladder in good condition?			
(15) Condition of the gatehouse?			
(16) Emergency plan completed for the dam?			
a. Posted in the gatehouse?			
(17) Other?			

D. Stilling Basin

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Do energy dissipaters show:			
a. Signs of deterioration?			
b. Are they covered with debris?			
(4) Other?			

ITEM	YES	NO	REMARKS
------	-----	----	---------

3. OUTLET WORKS (continued)

E. Downstream Channel

(1) Is the channel:			
a. Eroding or backcutting?			
b. Sloughing?			
c. Obstructed?			
(2) Is released water:			
a. Undercutting the outlet?			
b. Eroding the embankment?			
(3) Other?			

4. SPILLWAY

A. Description

(1) Location?			
(2) Type of Spillway?			
(3) Size of Spillway?			
(4) Spillway lining?			
(5) Is there a weir?			
(6) Is the spillway in good condition?			
(7) Any drains?			
a. Describe the condition of drains.			

B. Does spillway show:

(1) Any cracking concrete?			
(2) Any spalling concrete?			
(3) Any exposed reinforcement in the concrete?			
(4) Any erosion?			

ITEM	YES	NO	REMARKS
------	-----	----	---------

4. SPILLWAY (continued)

4. B. Does spillway show: (continued)

(5) Any slope sloughing?			
(6) Any obstructions?			
(7) Displacement or offset joints?			
(8) Loss of joint material?			
(9) Leakage at the joints?			
(10) Other?			

C. Do the energy dissipaters show:

(1) Signs of deterioration?			
(2) Any cracking?			
(3) Any spalling?			
(4) Any exposed reinforcement?			
(5) Are they covered with debris?			
(6) Other?			

D. Has release water:

(1) Eroded the embankment?			
(2) Undercut the outlet?			
(3) Eroded the downstream channel?			
(4) Other?			

E. Emergency Spillway

(1) Is there an emergency spillway?			(If YES, describe)

ITEM	YES	NO	REMARKS
------	-----	----	---------

5. RESERVOIR CONTROL

A) Recent upstream development?			
B) Recent downstream development?			
C) Slides in reservoir area?			
D) Change in reservoir operation?			
E) Large impoundment upstream?			
F) Any debris in the reservoir?			
G) Other?			

6. INSTRUMENTATION

A) List type(s) of instrumentation:			
B) In good condition?			
C) Read periodically?			
D) Is data available?			
E) Include all data gathered since last report.			

7. DOWNSTREAM CONDITION

A. Downstream Land Use.

This dam was inspected by:

Additional comments and recommendations.

APPENDIX C
O&M MANUAL DISTRIBUTION LIST

COTTONWOOD DAM O&M DISTRIBUTION LIST

	<u>Number Of Copies</u>
1. SWPB Kevin Smith Rob Kingery Brian Holling (2) Brandon Watne Dolores Eustice	6
2. DNRC Information Services Section	1
3. DNRC-WRD Bozeman Unit Office Kerri Strasheim	1
4. DNRC Dam Safety	1
5. Water Users Alan Johnstone -- President Les Arthun -- Secretary and Dam Operator Ken Arthun -- Director	3
6. State Library -- Attn: State publications Librarian	4
7. Extra	2
=====	
TOTAL	18

APPENDIX D

MONITORING WELL LOGS

BECK PIEZOMETER TABLE

Piezometer Table

Piez #1 Total Length = 10.00' Stick-up = 1.96' Total in ground = 8.04'
Elev = 5065.28'

Note: This piezometer was destroyed in 1999.

Piez #2 Total Length = 5.00' Stick-up = 1.35' Total in ground = 3.65' Elev
= 5058.61'

Piez #3 Total Length = 10.55' Stick-up = 1.60' Total in ground = 8.95'
Elev = 5059.12'

Piez #4 Total Length = 10.25' Stick-up = 2.20' Total in ground = 8.05'
Elev = 5054.95'

Piez #5 Total Length = 10.22' Stick-up = 1.60' Total in ground = 8.62'
Elev = 5054.11'

Piez #6 Total Length = 5.00' Stick-up = 1.10' Total in ground = 3.90'
Elev = 5053.48'

Piez #7 Total Length = 10.30' Stick-up = 1.10' Total in ground = 9.20'
Elev = 5050.61'

Piez #8 Total Length = 10.64' Stick-up = 1.65' Total in ground = 8.65'
Elev = 5055.02'



SOIL LOG OF BOREHOLE NO: DH1

(Page 1 of 2)

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : COTTONWOOD
DATE STARTED : 11/18/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5109.3	Sample Interval	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Field Blow Counts	Adjusted Blow Count (blows/foot)	Inches Recovered Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5109		0 to 2.9 SANDY LEAN CLAY with minimal ($<10\%$) gravel pebbles and fragments, dark brown, slightly moist, medium plasticity									
5	5104	X				SS	5 7 10	27	10.8/18	60%		
10	5099	X				SL	14 9 8	18	4/18	22%		Hit a rock, broke shoe in sampler Rock blocked sample
15	5094	X		CL		ST						15 to 17' % Finer #200 = 66% m = 20.9% LL=38% PL=17% PI=21% Dry Unit Weight = 107.2 pcf Moist Unit Weight = 129.6 pcf Fine content varies from 66 to 76%
20	5089	X				SS	3 2 5 3 5	6	15.6/18	87%		
		X				SS		10	18/18	100%		21.5' Estimating embankment foundation contact
25	5084	X				SL	3 5 5	9	16.8/18	93%		25.5 to 26' % Finer #200 = 77% m = 24.6 Dry Unit Weight = 85.5 pcf Moist Unit Weight = 106.6 pcf
30				SS						95%		29' Bedrock contact Stopped augering, begin coring Cored 1' (29 to 30') ROD = 33% poor

Hollow Stem Auger 4 1/2" ID Core Barrel HQ3
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"



SOIL LOG OF BOREHOLE NO: DH1

(Page 2 of 2)

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(406) 444-6646

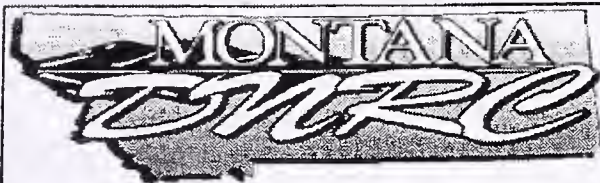
RESERVOIR : COTTONWOOD
DATE STARTED : 11/18/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5109.3	Sample Interval	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Field Blow Counts	Adjusted Blow Count (blows/foot)	Inches Recovered Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	5079		29 to 45 SANDSTONE, greenish gray to dark gray, extremely fractured, many fractures appear water bearing, minor calcite along fractures	SS						92%		Cored 5' (30 to 35') Appears entire reach carries water RQD = 45% poor
35	5074		29 to 32.5 sandstone, as above							91%		Cored 10' (35 to 45') Appear many fractures of reach carry water RQD = 32%
			32.5 to 33.8 sandstone, more clays, softer, olive green									
			33.8 to 39.1 light brown sandstone, finer grained									
40	5069		39.1 to 41.5 greenish gray sandstone, strongly fractured									Refer to digital photos in project files
			41.5 to 45 dark greenish gray sandstone, more competent									
45	5064		45 BOTTOM OF HOLE									
50	5059											
55	5054											
60												

Hollow Stem Auger 4 1/2" ID Core Barrel HQ3
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

03-29-2005 G:\WATER_RTW\RB-STAF\Bob A\Well Logs\Cottonwood Logs\Cottonwood DH-1 Soil bor



WELL COMPLETION LOG NO: DH1

(Page 1 of 1)

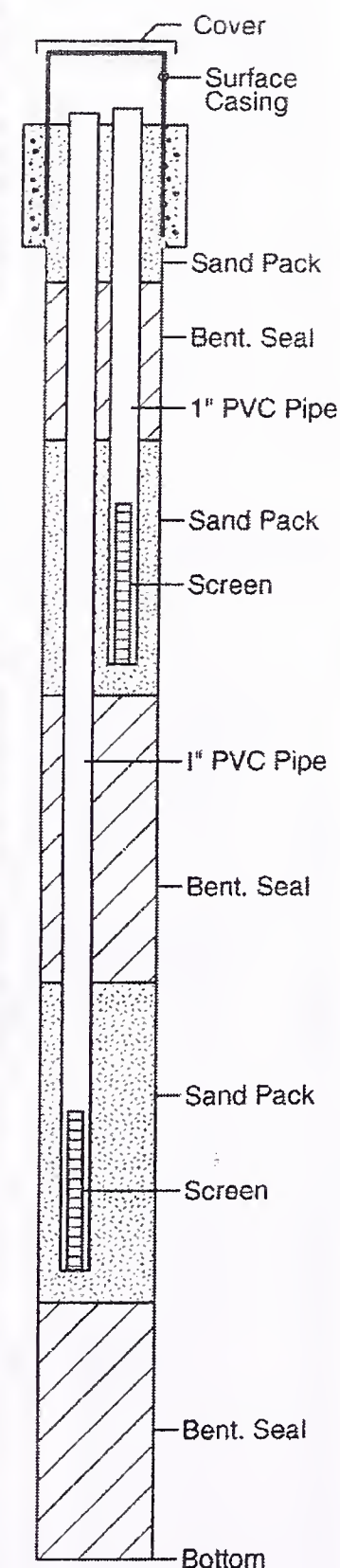
MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/18/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth In Feet	Surf. Elev. 5109.3	Well Construction Information	DESCRIPTION	Depth In Feet
0	5109	WELL CONSTRUCTION Date Compl. : 11/18/1999 Hole Diameter : 8 inch DNRC Rep. : Bob Arrington	0 to 5 SAND	0
5	5104	STANDPIPE Material : PVC pipe Diameter : 1 inch Joints : screwed Bottom Cap : glued	5 to 10 BENTONITE	5
10	5099	WELL SCREEN Material : PVC pipe Diameter : 1 inch Length : 5 feet Opening : .02 inch	10 to 18 SAND	10
15	5094	SAND PACK Material : Colorado Silica 10/20	12 to 17 SCREEN FOR DH1B	15
20	5089	ANNULUS Material : 3/8 inch Bentonite	18 to 27 BENTONITE	20
25	5084	WELL COVER Diameter : 7 inch Length : 5 feet	21.5 embankment/foundation contact	25
30	5079	NOTES: Surface Elev: 5109.34 feet DH1A TOP Elev: 5109.8 feet DH1B TOP Elev: 5109.61 feet Top of Cover Elev: 5110.0 feet (estimate)	27 to 37 SAND	30
35	5074	Northing: 10296.86 Easting: 9997.14	29 bedrock contact	35
40	5069	Surveyed By: Mike Lesnik Date Surveyed: 1/25/2000	31 to 36 SCREEN FOR DH1A	40
45	5064		37 to 45 BENTONITE	45
50			45 BOTTOM OF HOLE	50

Well1: DH-1A
Well2: DH-1B





SOIL LOG OF BOREHOLE NO: DH2

(Page 1 of 2)

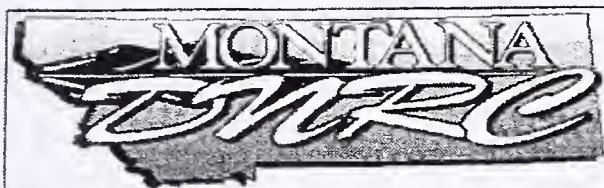
MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/15/1999
DATE COMPLETED : 11/17/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5108.9	Sample	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
			DESCRIPTION									
0	5108		0 to 20' SANDY LEAN CLAY with minimal ($<10\%$) gravel pebbles and fragments, dark brown, slightly moist, medium plasticity									
5	5103											
10	5098	☒		CL		SS	4 6 12	20	13.2/18	73%		
15	5093	☒				SL	9 8 9	16	13.2/18	73%		15.5 to 16.0' % Finer #200 = 50% m = 18.1% dry unit weight = 112.7 pcf moist unit weight = 133.1 pcf
20	5088	☒	20 to 45' CLAYEY SAND with some gravel pebbles and fragments, brown, slightly moist, medium plasticity			ST			20/22	91%		20.0 to 22.0' % Finer #200 = 44% m = 18.1% dry unit weight = 112.7 pcf moist unit weight = 133.1 pcf LL=39% PL=18% PI= 21% cu test: c=2.6 phi=10.0 Effective c=0.98 phi=32.2
25	5083	☒		SC		SS	4 5 4	8	18/18	100%		
30	5078	☒	30.5 to 37.5' 25% small gravels of sandstone			SL	6 8 11	15	16.8/18	93%		30.5 to 31.0' % Finer #200 = 62% m = 17.8 % dry unit weight = 107.8 pcf moist unit weight = 127.0 pcf
35												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner SPoon OD 2.5" ID 2.0"



SOIL LOG OF BOREHOLE NO: DH2

(Page 2 of 2)

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601

Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/15/1999
DATE COMPLETED : 11/17/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5108.9	Sample	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
35	5073		35 to 45' CLAYEY SAND									36' Estimated embankment foundation contact
		⊗	35.5 to 36.5 grass root fragments			SS	13	10	19.2/24	80%		37.5 to 38.0' % Finer #200 = 45.7%
40	5068		38.5 to 39.5 50 to 60% sandstone fragments, rounded river cobbles, wet, loose	SC								
			40 to 45 augering easy									
45	5063	⊗	45 to 64' SANDSTONE, light gray to gray, medium grained			SS	12 50		10/10	100%		45' Bedrock contact Stopped augering, begin coring
		—	45 to 50.5' weathered, extremely fractured, entire reach appears water bearing							45%		45 to 50.5' Cored 5.5' Recovered 2.5' RQD = .07% very poor
50	5058	—	50.5 to 55' contains rounded pebble conglomerate rocks, very fractured, several fractures appear water bearing							89%		50.5 to 55' Cored 4.5' Recovered 4' RQD = 60% fair
55	5053	—	55 to 64' fairly competent, contains some conglomerate rock, several fractures appear water bearing	SS						100%		55 to 64' Cored 9' Recoverd 9' RQD = 85% good
60	5048		56 to 57.5' rounder pebble conglomerate									
			61 to 62.8 conglomerate, rounded igneous pebbles up to 1.5" diameter									
			Minor calcite along fractures in all of above.									Refer to digital photos in project files
65	5043		64' BOTTOM OF HOLE									
70												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner SPoon OD 2.5" ID 2.0"



WELL COMPLETION LOG NO: DH2

(Page 1 of 1)

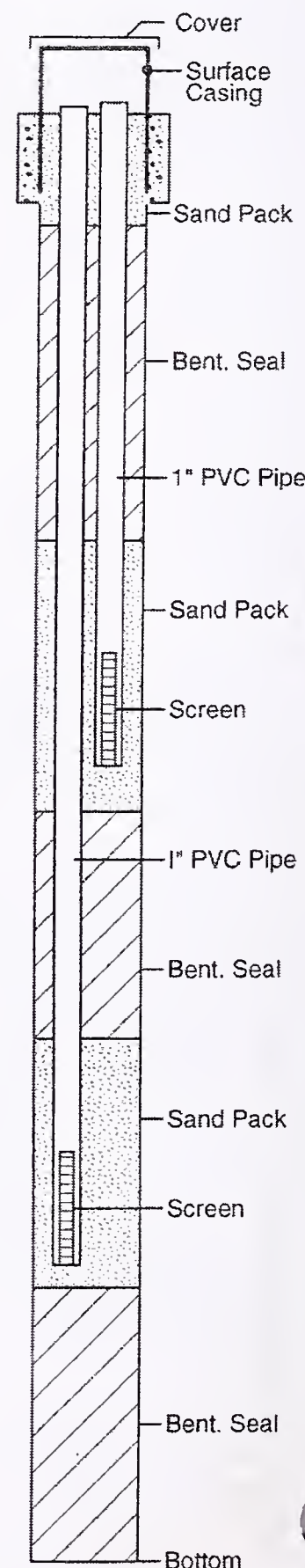
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Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/15/1999
DATE COMPLETED : 11/17/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Strata Star 15
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

Depth In Feet	Surf. Elev. 5108.9	Well Construction Information	DESCRIPTION	Depth In Feet
0	5108	WELL CONSTRUCTION Date Compl. : 11/17/1999 Hole Diameter : 8 inch DNRC Rep. : Bob Arrington	0 to 5 SAND	0
5	5103	STANDPIPE Material : PVC pipe Diameter : 1 inch Joints : screwed Bottom Cap : glued	5 to 19 BENTONITE	5
10	5098	WELL SCREEN Material : PVC pipe Diameter : 1 inch Length : 5 feet Opening : .02 inch		10
15	5093			15
20	5088	SAND PACK Material : Colorado Silica 10/20	19 to 31 SAND	20
25	5083	ANNULUS Material : 3/8 inch Bentonite	24 to 29 SCREEN FOR DH2B	25
30	5078	WELL COVER Diameter : 7 inch Length : 5 feet	31 to 41 BENTONITE	30
35	5073	NOTES: Surface Elev: 5108.90 feet DH2A TOP Elev: 5109.25 feet DH2B TOP Elev: 5109.09 feet Top of Cover Elev: 5109.5 feet (estimate)	36 embankment/foundation contact	35
40	5068		41 to 52 SAND	40
45	5063	Northing: 10125.14	45 bedrock contact	45
50	5058	Easting: 9995.13	46 to 51 SCREEN FOR DH2A	50
55	5053	Surveyed By: Mike Lesnik	52 to 64 BENTONITE	55
60	5048	Date Surveyed: 1/25/2000		60
65			64 BOTTOM OF HOLE	65

Well1: DH-2A
Well2: DH-2B



03-29-2005 G:\WATER_RT\WFB-STAF\Bob A\Well Logs\Cottonwood Logs\Cottonwood DH-2 WC.bor



SOIL LOG OF BOREHOLE NO: DH3

(Page 1 of 1)

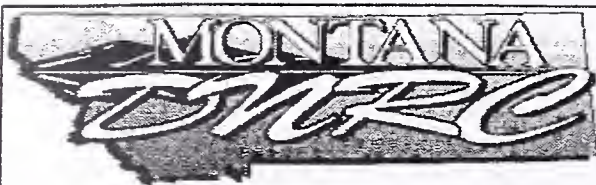
MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/15/1999
DATE COMPLETED : 11/16/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Tim Kuehn
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5092.2	Sample Interval	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts	Inches Recovered Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5092		0 to 14.5' SANDY LEAN CLAY with minimal ($<15\%$) gravel, brown to dark brown, slightly moist, medium plasticity									
5	5087	☒	5 to 6.5' sandy gravel	CL		SL	8 12 20	41	14/18	78%		
10	5082	☒				SS	8 17 41	33				
15	5077		14.5 to 33' SANDSTONE, fine grained, gray									14.5' Bedrock contact Stopped augering, begin coring
			14 to 17' greenish gray, weathered, extremely fractured, high clay content							100%		14.5 to 19.5' Cored 5' Recovered 5' RQD = 33% poor
20	5072		17 to 19.5' reddish brown gray, competent rock							86%		19.5 to 23' Cored 3.5' Recovered 3' RQD = 24% very poor
25	5067		19.5 to 23.5 reddish brown gray, fairly competent, fractures occur 2" to 5" spacing	SS						90%		23 to 33' Cored 10' Recovered 9' RQD = 37% poor
			23.5 to 26' greenish gray, weathered, fractures, increased amount of clay particles in fractures									
30	5062		26 to 33 greenish gray to medium gray, competent rock									
			Minor calcite along fractures in all of above.									Refer to digital photos in project files.
35			33 BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"



WELL COMPLETION LOG NO: DH3

(Page 1 of 1)

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(406) 444-6646

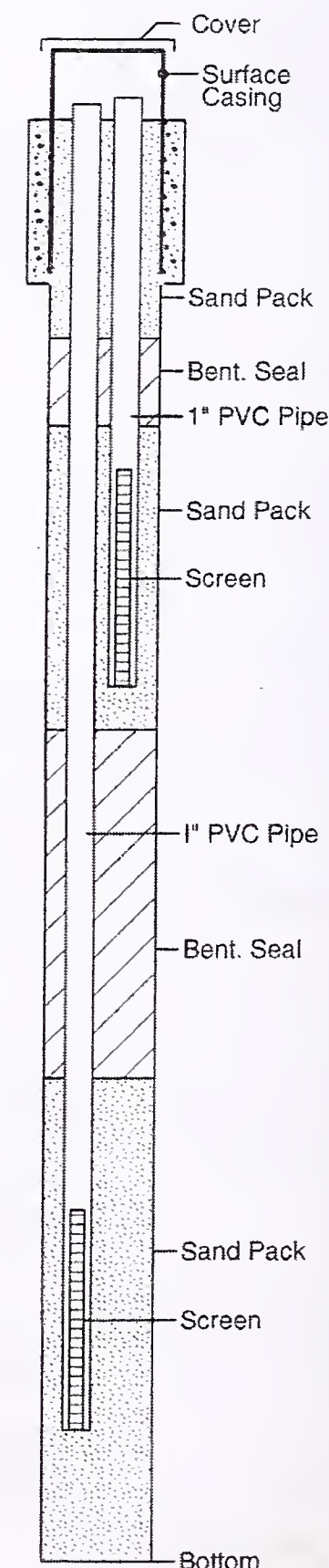
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DATE STARTED : 11/15/1999
DATE COMPLETED : 11/16/1999
DRILL COMPANY : Bush Drilling
DRILLER :

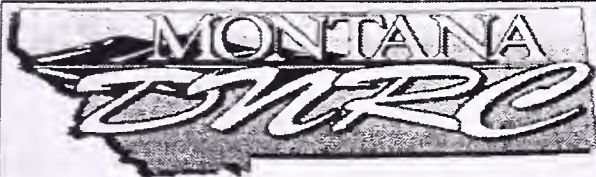
DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Tim Kuehn
APPROVED BY : Kevin Smith

Depth In Feet	Surf. Elev. 5092.2	Well Construction Information	DESCRIPTION	Depth In Feet
0	5092	WELL CONSTRUCTION Date Compl. : 11/16/1999 Hole Diameter : 8 inch DNRC Rep. : Tim Kuehn	0 to 5 SAND	0
5	5087	STANDPIPE Material : PVC pipe Diameter : 1 inch Joints : screwed Bottom Cap : glued	5 to 7 BENTONITE	5
10	5082	WELL SCREEN Material : PVC pipe Diameter : 1 inch Length : 5 feet Opening : .02 inch	7 to 14 SAND	10
		SAND PACK Material : Colorado Silica 10/20	8 to 13 SCREEN FOR DH3B	
		ANNULUS Material : 3/8 inch Bentonite	14 to 22 BENTONITE	
15	5077	WELL COVER Diameter : 7 inch Length : 5 feet	14.5 bedrock contact	15
20	5072	NOTES: Surface Elev: 5092.20 feet DH3A TOP Elev: 5092.46 feet DH3B TOP Elev: 5092.22 feet Top of Cover Elev: 5092.7 feet (estimate) Northing: 10304.78 Easting: 10053.45 Surveyed By: Mike Lesnik Date Surveyed: 1/25/2000	22 to 33 SAND	20
25	5067		25 to 30 SCREEN FOR DH3A	25
30	5062		33 BOTTOM OF HOLE	30
35				35

Well1: DH-3A

Well2: DH-3B





SOIL LOG OF BOREHOLE NO: DH4

(Page 1 of 1)

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/17/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Jim Beck
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5084.4	Sample Interval	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
			DESCRIPTION									
0	5084		0 to 10' SANDY LEAN CLAY with minimal ($<15\%$) gravel, brown to dark brown to gray, slightly moist									
5	5079	☒	6 to 7.5' wet zone	CL		SS	$\frac{3}{7}$ 14	27	14.4/18	80%		
10	5074	☒	10 to 16' SILTSTONE, weathered, gray to gray green, hard, dry, clayey silt	SS		SL	23 50		11/18	61%		10' Bedrock contact 10 to 10.4' % Finer #200 = 91.2%
15	5069	☒	16 to 33.5' SANDSTONE, gray to redish brown gray			SS	32 50		8.5/18	47%		15' Stop augering, begin coring 15 to 20' Cored 5' Recovered 4.5' RQD = 72%
20	5064		16 to 23.5' approximately 2 fractures per foot, all fractures appear water bearing, minor calcite along fractures							91%		20 to 23.5' Cored 3.5' Recovered 3.2' RQD = 31%
25	5059		23.5' to 33.5' less friable than above, gray, competent rock, probably transition from erosion surface to hard bedrock.	SS						100%		23.5 to 28.5' Cored 5' Recovered 5' RQD = 92%
30	5054									100%		28.5 to 33.5' Cored 5' Recovered 5' RQD = 88%
35			33.5' BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"



WELL COMPLETION LOG NO: DH4

(Page 1 of 1)

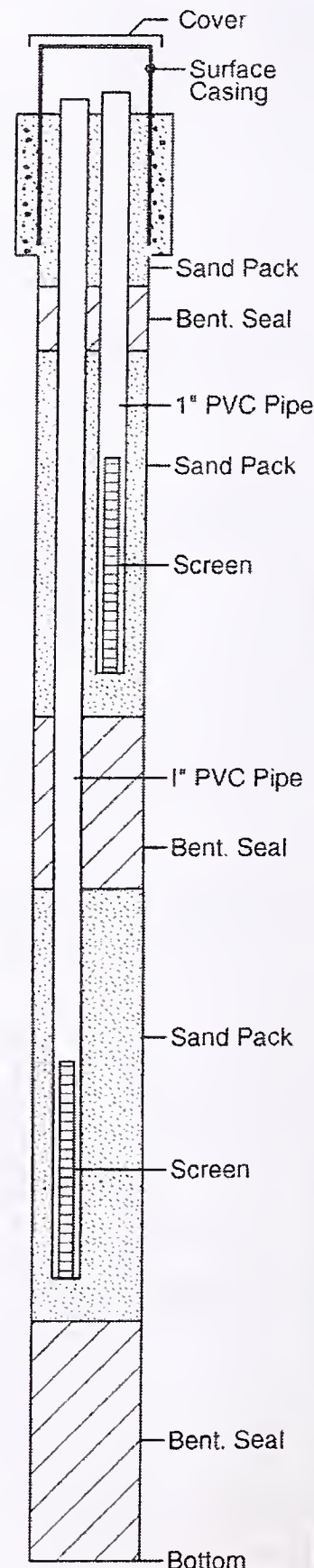
MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/17/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Jim Beck
APPROVED BY : Kevin Smith

Depth In Feet	Surf. Elev. 5084.4	Well Construction Information	DESCRIPTION	Depth In Feet
0	5084	WELL CONSTRUCTION Date Compl. : 11/18/1999 Hole Diameter : 8 inch DNRC Rep. : Jim Beck STANDPIPE Material : PVC pipe Diameter : 1 inch Joints : screwed Bottom Cap : glued WELL SCREEN Material : PVC pipe Diameter : 1 inch Length : 5 feet Opening : .02 inch	0 to 4 SAND	0
5	5079		4 to 5.5 BENTONITE	5
10	5074		5.5 to 14 SAND	10
			10 bedrock contact	
			8 to 13 SCREEN FOR DH4B	
15	5069	SAND PACK Material : Colorado Silica 10/20 ANNULUS Material : 3/8 inch Bentonite WELL COVER Diameter : 7 inch Length : 5 feet	14 to 18 BENTONITE	15
20	5064	NOTES: Surface Elev: 5084.39 feet DH4A TOP Elev: 5084.46 feet DH4B TOP Elev: 5084.34 feet Top of Cover Elev: 5084.7 feet (estimate) Northing: 10238.23 Easting: 10064.43 Surveyed By: Mike Lesnik Date Surveyed: 1/25/2000	18 to 28 SAND	20
25	5059		22 to 27 SCREEN FOR DH4A	25
30	5054		28 to 33.5 BENTONITE	30
35			33.5 BOTTOM OF HOLE	35

Well1: DH-4A
Well2: DH-4B





SOIL LOG OF BOREHOLE NO: DH5

(Page 1 of 1)

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P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/16/1999
DATE COMPLETED : 11/18/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Tim Kuehn
APPROVED BY : Kevin Smith

Depth in Feet	Surf. Elev. 5078.8	Sample Interval	SAMPLER TYPE SS Split spoon SL Split Spoon Brass Liners ST Shelby Tube	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5078		0 to 5' GRAVELLY TOPSOIL, occasional cobbles, brown to dark brown, dry	GP								
5	5073	⊗	5 to 10' SANDY LEAN CLAY with some gravels, dark brown, moist	CL		SS	8 10 7	23	12/18	67%		5 to 6.5' % Finer #200 = 50%
10	5068	⊗	10 to 15' SAND, saturated	SP		SL	2 4 6	9	0/18	0%		
15	5063	⊗	15 to 33.5' SANDSTONE, light gray to gray, numerous fractures, most fractures appear water bearing			SS	14 50		6.7/18	37%		15' Bedrock contact Stop augering, begin coring
20	5058		15 to 16.5' weathered, soft							80%		15 to 20' Cored 5' Recovered 4' RQD = 54%
25	5053		16.2 to 17' siltstone							91%		20 to 23.5' Cored 3.5' Recovered 3.2' RQD = 55%
30	5048		17 to 21' sandstone with rip-up clasts of siltstone	SS						100%		23.5 to 28.5' Cored 5' Recovered 5' RQD = 92%
			21.5 to 28.8' conglomerate with sandstone matrix									
			28.8 to 33.5' sandstone							100%		28.5 to 33.5' Cored 5' Recovered 5' RQD = 99%
35			33.5 BOTTOM OF HOLE									Refer to digital photos in project file.

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
HAMMER 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"



WELL COMPLETION LOG NO: DH5

(Page 1 of 1)

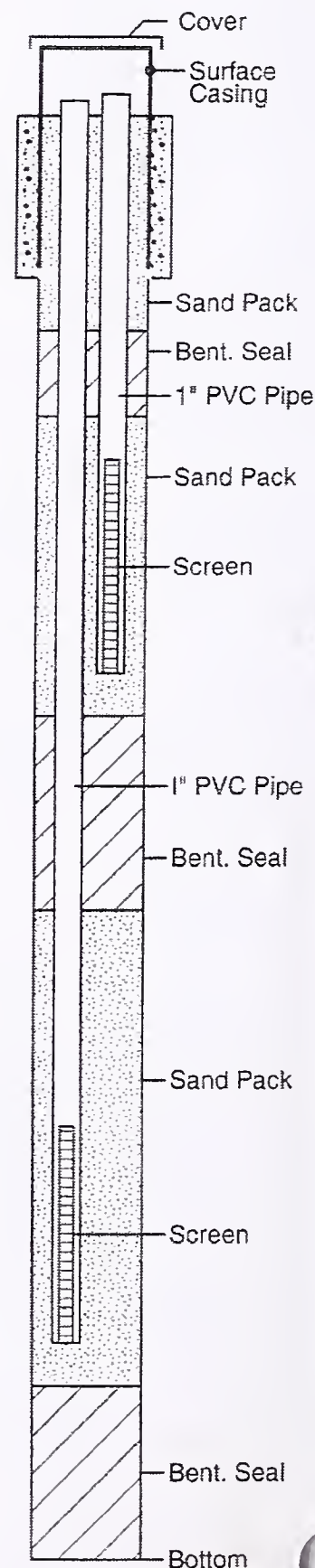
MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Cottonwood
DATE STARTED : 11/16/1999
DATE COMPLETED : 11/17/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Kuehn/Beck
APPROVED BY : Kevin Smith

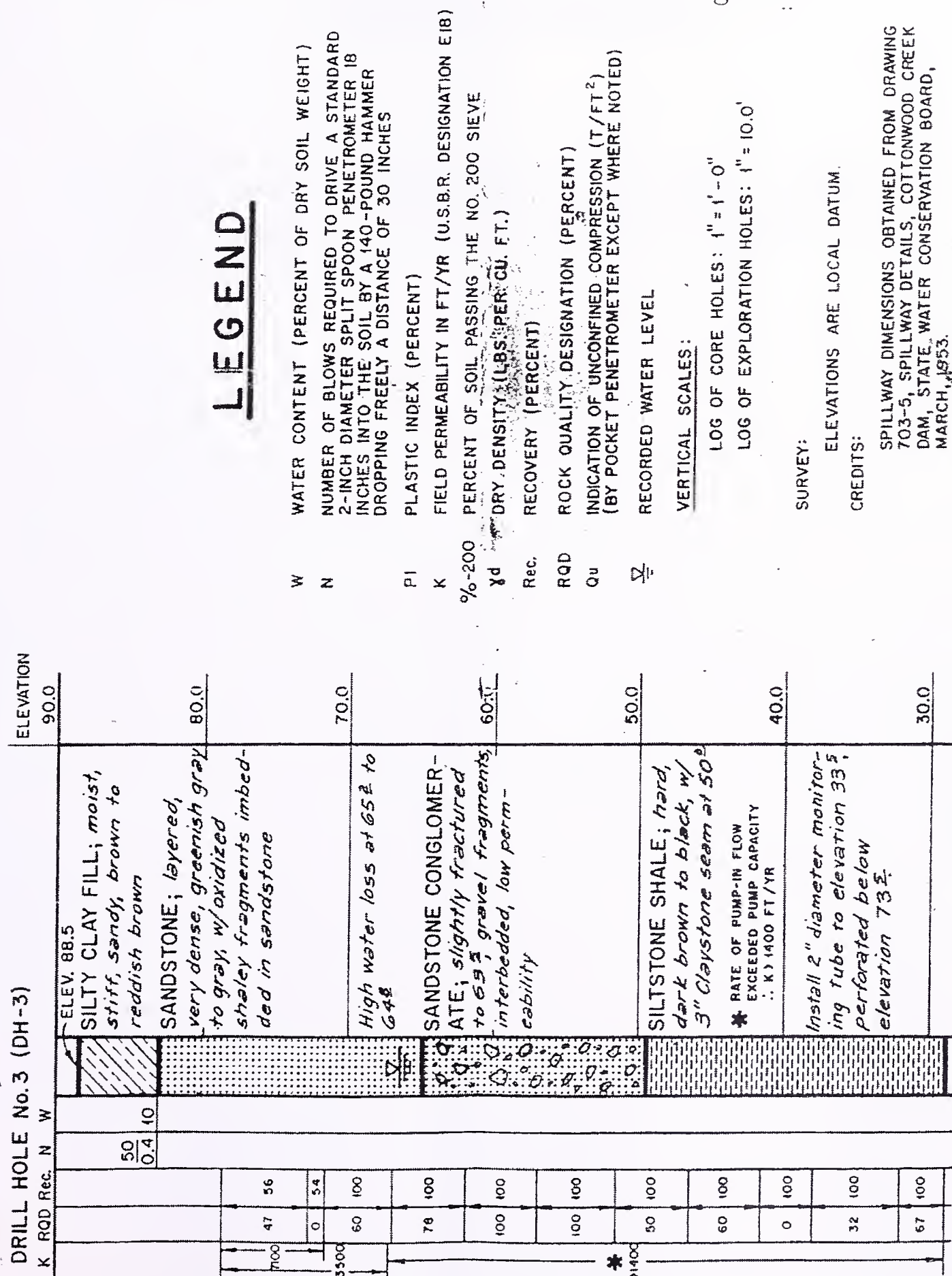
Depth In Feet	Surf. Elev. 5078.8	Well Construction Information	DESCRIPTION	Depth In Feet
0	5078	WELL CONSTRUCTION Date Compl. : 11/17/1999 Hole Diameter : 8 inch DNRC Rep. : Jim Beck	0 to 5 SAND	0
5	5073	STANDPIPE Material : PVC pipe Diameter : 1 inch Joints : screwed Bottom Cap : glued	5 to 7 BENTONITE	5
10	5068	WELL SCREEN Material : PVC pipe Diameter : 1 inch Length : 5 feet Opening : .02 inch	7 to 14 SAND 8 to 13 SCREEN FOR DH5B	10
15	5063	SAND PACK Material : Colorado Silica 10/20 ANNULUS Material : 3/8 inch Bentonite WELL COVER Diameter : 7 inch Length : 5 feet	14 to 18.5 BENTONITE 15 bedrock contact	15
20	5058	NOTES: Surface Elev: 5078.80 feet DH5A TOP Elev: 5079.03 feet DH5B TOP Elev: 5078.90 feet Top of Cover Elev: 5079.30 feet (estimate) Northing: 10134.77	18.5 to 29.5 SAND	20
25	5053	Easting: 10076.73 Surveyed By: Mike Lesnik Date Surveyed: 1/25/2000	23.5 to 28.5 SCREEN FOR DH5A	25
30	5048		29.5 to 33.5 BENTONITE	30
35			33.5 BOTTOM OF HOLE	35

Well1: DH-5A
Well2: DH-5B



Drill Hole No. 6 (DH-6)

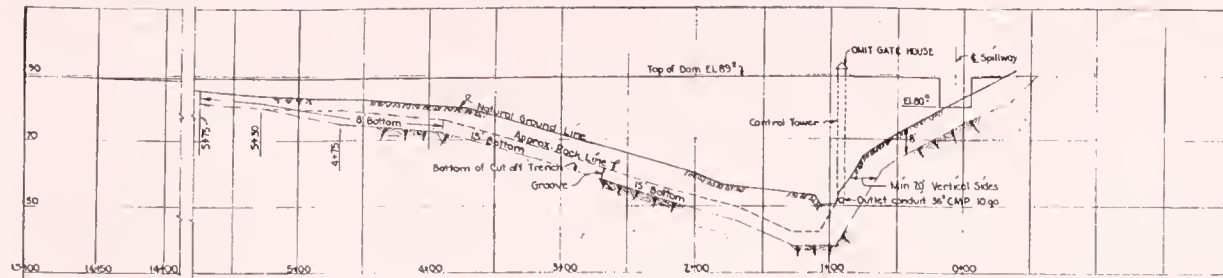
Note: Three drill holes were drilled in May 1982, but two of the holes were destroyed when the spillway was rebuilt. The remaining hole is located on the south side of the spillway. It was originally identified as DH-3, but has been renumbered to DH-6 to mesh with the drill holes drilled in 1999. See Figure 4 that shows the location of this monitoring well.



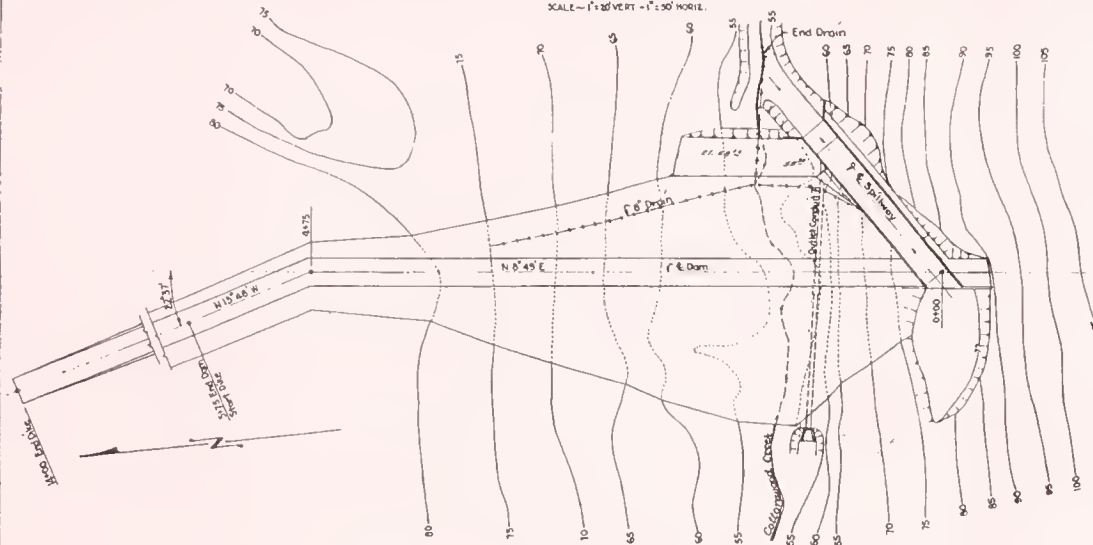
APPENDIX E

PROJECT DRAWINGS

(NOTE: These reduced project drawings are design drawings and not "As Builts". These drawing should be used for reference only. The SWPB has the full size project drawings.)



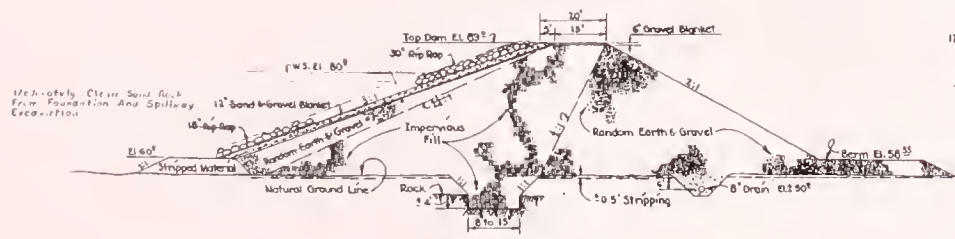
PROFILE
SCALE - 1" = 20' VERT - 1" = 50' HORIZ.



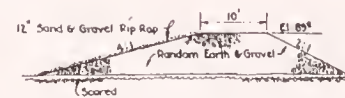
PLAN
SCALE - 1" = 50'



RESERVOIR MAP
SCALE - 1" = 500'



TYPICAL SECTION
SCALE - 1" = 10'
END OF DAM SECTION @ ROCK RIP RAP AT 5+75

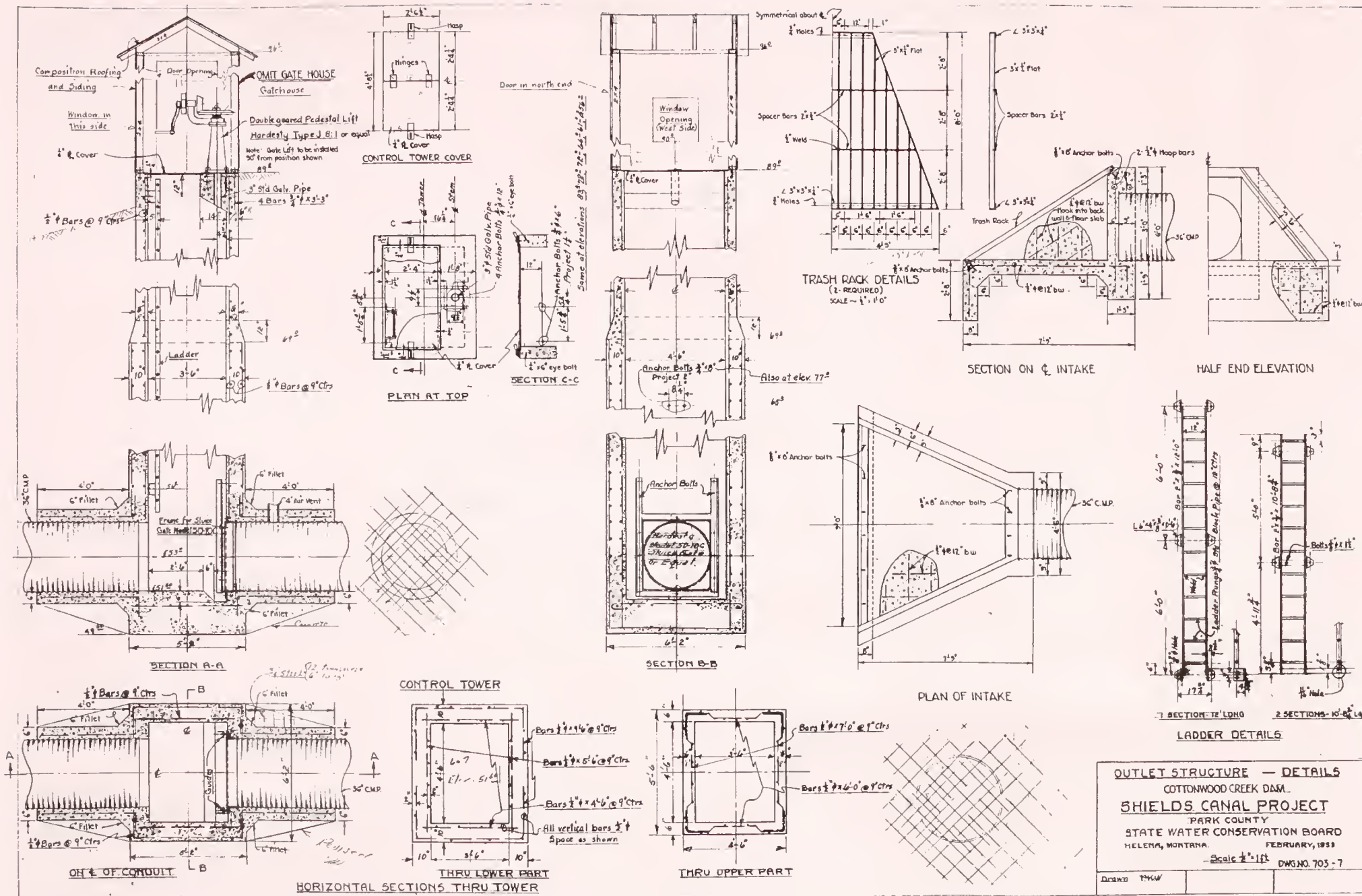


TYPICAL DIKE SECTION
SCALE - 1" = 10'
DIKE SECTION FROM 5+75 TO 14+00
END GRAVEL RIP RAP AT 8+50

DETAILS OF DAM - COTTONWOOD CREEK
SHIELDS CANAL PROJECT
PARK COUNTY

STATE WATER CONSERVATION BOARD
HELENA, MONTANA APRIL 1953
SCALE AS SHOWN

OWG NO. 703-4





H&M ASSOCIATES
 ENGINEERS-PLANNERS
 Branch Offices:
 Airport Industrial Park
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 Billings, Montana 59107
 Sheridan, Wyoming

